The Equity of Environmental Policy: Evidence from Smog Check

Joseph S. Shapiro and Arthur A. van Benthem

This project quantifies the compliance costs, environmental benefits, and social welfare impacts of an important environmental policy for transportation, in aggregate and across income, race, and ethnic groups. We apply a new research design to microdata with unprecedented environmental, economic, and geographic detail. The data link vehicle remote sensing interpreted via machine learning, neighborhood-to-neighborhood travel data from aggregated cell phone pings, an econometric model of pollution dispersion, environmental compliance costs from administrative records, and individual vehicle registrations.

Researchers and policymakers argue that many environmental policies create a disproportionate burden for low-income and minority communities because households in these communities spend a relatively larger share of their budgets on energy- and pollution-intensive goods (Hassett, Mathur, and Metcalf 2009; Grainger and Kolstad 2010; Williams et al. 2015). In many countries, concerns that environmental policy increases inequality undermine political support for climate change policy (Dechezlepretre et al. 2022; Douenne 2022).

This research studies a countervailing force that may temper this concern: energy-consuming durable goods like gasoline vehicles emit pollution in the communities where they are used. Even if environmental policies that tax or regulate such goods create disproportionate compliance costs for low-income and minority communities, they may also provide disproportionate environmental benefits for the low-income and minority residents who live and breathe in these communities. Whether these environmental policies' potentially regressive compliance costs outweigh these policies' potentially progressive environmental benefits is an empirical question this research examines.

We study this question using new data and a new research design to analyze vehicle inspection and maintenance programs, i.e., smog check policies, which are an important environmental policy for transportation in the US, EU, Brazil, Russia, India, China, Mexico, and most other high- and middle-income countries. Used vehicles undergo mandatory regular inspections to test the vehicle's emissions control system and emission rates. Vehicles failing inspections must undergo costly repairs at the owner's expense to meet environmental standards.

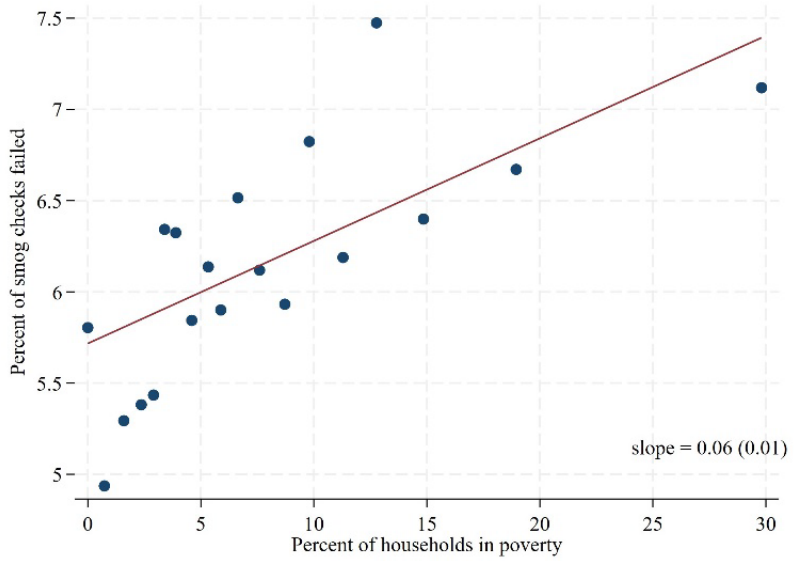
Economics papers largely lament that smog check policies allow vehicle owners to cheat (Oliva 2015) and undertake short-term repairs (Merel et al. 2014), or that these policies in other ways create compliance costs without corresponding broad and durable environmental benefits (Sanders and Sandler 2020).

Regressive Compliance Costs

We first document that smog check programs create disproportionate costs for low-income and minority households, echoing the aforementioned concerns for other environmental policies. To measure the relationship between smog check compliance costs and household demographics, we link smog check inspection microdata in several states to public Census data on the income and demographics of the Census block group where the inspected vehicle is registered.

Preliminary results in Figure 1 show that households in low-income and minority communities have vehicles with higher pollution levels. As a result, these households have a higher probability of failing smog check inspections; complete more smog check inspections to obtain a passing test, thus requiring more owner time and payment of test fees; and spend more on repairs in order to pass inspections. This finding echoes our prior work, which found that low-income households own older vehicles, which emit disproportionate levels of pollution (Jacobsen et al. 2023).

Figure 1: Vehicles Registered in Low-Income Zip Codes are More Likely to Fail Smog Check



New Data and Research Design to Measure Environmental Benefits

We then leverage new vehicle remote sensing data to quantify the aggregate and distributional environmental benefits of smog check policies. Much research questions whether these policies have *any* durable benefits.

Vehicle remote sensing data, which are largely new to economic research, use roadside infrared or ultraviolet beams linked to devices that quantify pollution in each vehicle's exhaust plume.[1] These data have several benefits. First, they can obtain weekly or monthly readings of an individual vehicle's emission rate. Second, they are largely impervious to short-term evasion strategies, partly since most drivers are unaware that they are even passing a remote sensing detector. Third, by photographing the vehicle's license plate and linking it to registration records, remote sensing systems determine each vehicle's full Vehicle Identification Number (VIN), which lets us link remote sensing readings to other vehicle data. Fourth, we have trained a random forest machine learning algorithm to translate remote sensing data from raw readings, which are difficult to interpret economically, to standard units (grams per mile). Our algorithm matches remote sensing

[1] "Remote sensing" typically denotes data collected by satellites, airplanes, or other aerial imagery. Vehicle remote sensing has the same name but is collected by roadside devices, not aerial imagery. We believe the only existing use of vehicle remote sensing data in economic research is in a limited sensitivity analysis for an appendix of our prior research for one state, which had no way to interpret magnitudes of remote sensing readings (Jacobsen et al. 2022).

readings with a smog check inspection reading in standard units taken just before the remote sensing reading. We train a random forest to use data on the remote sensing reading, vehicle attributes, and weather to predict the smog check test result. The algorithm has high predictive accuracy in a held-out test set.

We quantify the environmental benefits of smog check by combining remote sensing data with idiosyncratic variation in the precise timing of smog check inspections and failures:

$$lnP_{it} = \Sigma_\tau \beta_\tau 1[t \text{ is } \tau \text{ quarters since } i \text{ failed smog check}] + \mu_i + \eta_t + \varepsilon_{it} \quad (1)$$

Here P_{it} represents the remote sensing pollution reading for VIN i on day t. Additionally, μ_i are VIN fixed effects, η_t are day fixed effects, and ε_{it} is a regression error, clustered by VIN. The coefficients β_τ represent the difference in emission rates for vehicle i in the quarters before versus after a failed smog check inspection. We also report estimates comparing passing versus failing smog checks. We plot the β_τ indicators against quarters since a smog check. We use methods robust to heterogeneous treatment timing and differential trends (Goodman-Bacon 2021).

Figure 2 plots our preliminary estimates, using one state where we have so far setup the required initial data (Colorado). The y-axis shows our estimates of β_τ from equation (1). In quarters before an emissions inspection, vehicles failing smog check and comparison vehicles have similar emission trends, as the point estimates are close to zero and lack a trend. Inspections decrease a vehicle's emissions by 13 percent ($p<0.01$) on average over the two years following a smog check. The emission rate remains about 13 percent lower for a full two years after the inspection. This graph includes two years on either side of an inspection because used vehicles in these data must undergo smog check tests every two years.

Figure 2: Smog Check Inspections Decrease Vehicle Remote Sensing Emissions

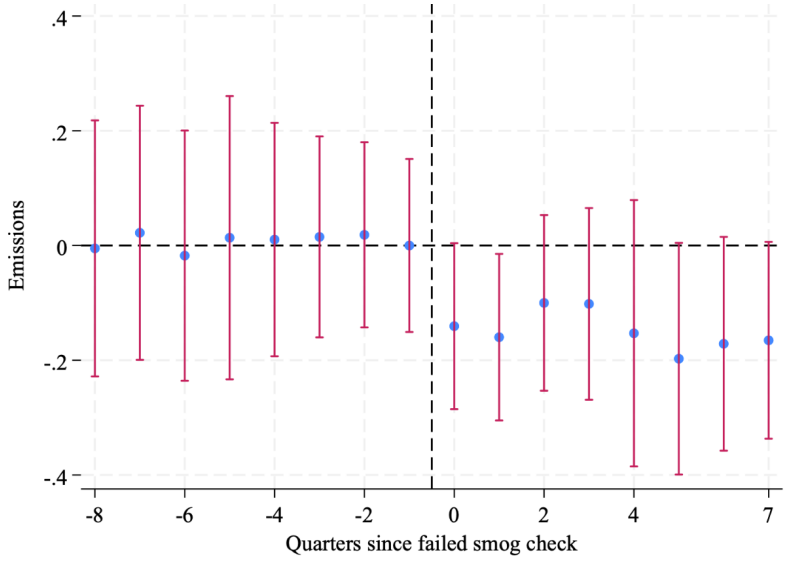


Figure 2 suggests that smog check causes large and sustained decreases in vehicle emissions. We further analyze how failing smog check for a specific pollutant affects remote sensing readings for that pollutant versus others; analyze vehicles of different ages and model years; and overlay this

research design with a regression discontinuity which compares vehicles that marginally failed smog check against vehicles that did not.

Distribution of Environmental Benefits

Which income and demographic groups obtain the environmental benefits of smog checks documented in Figure 2, and how do these health and welfare benefits compare to the compliance costs documented in Figure 1? Our vehicle registration microdata identify the Census block group where each VIN is registered. By linking these to the Population Census and American Communities Survey, we observe the mean income, race, and ethnicity of Census block groups where smog check improves vehicle emissions.

Because vehicles travel between communities, we need to know where vehicles are driven, not only where they are registered. We use cell phone records of aggregate bilateral driving patterns between Census block groups, which we obtained from a private vendor (AirSage). For each block group in metro areas that have the other data required for this study, the data record the share of trips that travel to each other Census block group. We combine these data with the Google Maps API to determine, for the mean vehicle registered in a block group, what share of miles travelled occur in each other block group.

We combine these travel data with spatially resolved information on how pollution emissions affect ambient air quality. We econometrically estimate pollution dispersion, using the combination of roadway vehicle miles traveled (VMT) and emissions data with ambient pollution monitoring data. Existing work suggests that much of the emissions from roadways fall within 200 meters downwind, so we will also report estimates which approximate dispersion patterns with this type of simpler rule of thumb.

Finally, we link these changes in ambient air quality to concentration-response functions from published literature describing how changing ambient air quality affects mortality rates, an endpoint which accounts for most health damages from pollution. As in Shapiro and Walker (2024), we use concentration-response functions from four different epidemiological and econometric analyses, which have similar magnitudes. We multiply estimated changes in mortality by prevailing estimates of the value of a statistical life to measure marginal willingness to pay for these environmental improvements, separately for each demographic group.

The ultimate output of this analysis will be a distributional social welfare analysis for regulated areas overall and separately for Blacks, Whites, Hispanic, Asian-American, and low-income residents. We will estimate compliance costs, environmental benefits, and the comparison, representing social welfare impacts.

Research team. The research team includes Joseph S. Shapiro, Associate Professor at UC Berkeley in Agricultural & Resource Economics and the Department of Economics; and Arthur A. van Benthem, Associate Professor of Business Economics and Public Policy at the University of Pennsylvania, Wharton School. Shapiro and van Benthem have a history of successful collaboration on these topics, including two grants from the National Science Foundation Social and Economic Sciences, and a coauthored paper in the QJE on related topics.

Conflict of interest statement. The researchers have no financial or other interests that might bear on the proposed work.

Relevance to the Department of Transportation (DOT). Pollution from US vehicles affects DOT decisions like investments in public transit and clean fueling infrastructure. Pollution from older vehicles affects the need for these cleaner transit investments as the US transitions to electric vehicles. Executive orders from the federal government have guided federal agencies to analyze how regulations affect the environment in low-income and minority communities. This paper also describes a general approach to assess the distribution of costs and benefits from policies affecting pollution, which is relevant to a range of DOT investments.

Bibliography

Dechezlepretre, A , A Fabre, T Kruse, B Planterose, AS Chico, and S Stantcheva. 2022. "Fighting Climate Change: International Attitudes Toward Climate Policies." NBER WP 30265.

Douenne, T and A Fabre. 2022. "Yellow Vests, Pessimistic Beliefs, and Carbon Tax Aversion." *American Economic Journal: Economic Policy*.

Goodman-Bacon, A. 2021. "Differences-in-Differences with Heterogeneous Treatment Timing." *Journal of Econometrics*.

Grainger, CA, and CD Kolstad. 2010. "Why Pays a Price on Carbon?" *Environmental and Resource Economics*.

Goulder, LH, MAC Hafstead, G Kim, and X Long. 2019. "Impacts of a carbon tax across US household income groups: What are the equity-efficiency trade-offs?" *J Public Economics*.

Hassett, KA, A Mathur, and GE Metcalf. 2009. "The Incidence of a U.S. Carbon Tax: A Lifetime and Regional Analysis." *The Energy Journal*.

Jacobsen, MR, JM Sallee, JS Shapiro, and AA van Benthem. 2023. "Regulating Untaxable Externalities: Are Vehicle Exhaust Standards Effective and Efficient?" *Quarterly Journal of Economics*

Merel, P, A Smith, J Williams, and E Wimberger. 2014. "Cars on crutches: How much abatement do smog check repairs actually provide?" *Journal of Environmental Economics and Management*.

Oliva, P. 2015. "Environmental regulations and corruption: Automobile emissions in Mexico City." *Journal of Political Economy*

Sanders, NJ, and R Sandler. 2020. "Technology and the Effectiveness of Regulatory Programs over Time: Vehicle Emissions and Smog Checks with a Changing Fleet." *Journal of the Association of Environmental and Resource Economists*.

Shapiro, JS, and R Walker. 2024. "Is Air Pollution Regulation Too Lenient? Evidence from US Offset Markets" Mimeo, UC Berkeley.